

Incorporating DER Benefits in Power Delivery System Planning

New Power Technologies *Energynet*[®] Overview

January 8, 2015

Top Level

- **DER ability to improve grid performance is well-established.**
- **Not all DER is grid-beneficial. Grid-beneficial DER is location and attribute-specific.**
- **Tools and techniques to rigorously identify grid-beneficial DER are proven.**

Nomenclature

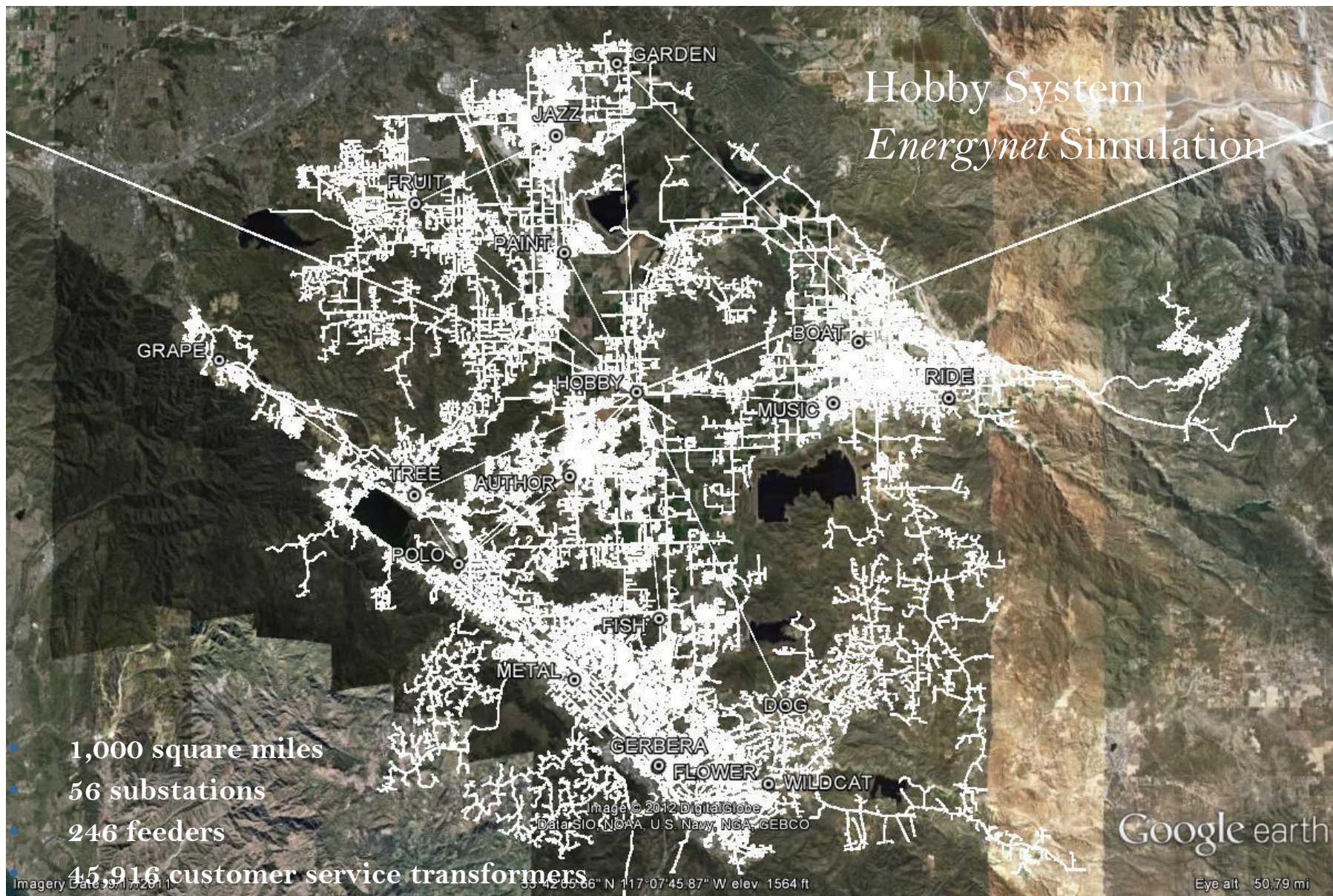
- **DER (distributed energy resources):**
 - Distributed generation
 - Demand response
 - Storage (generation and demand response, four quadrants)
 - Close to load
- **Grid (power delivery network):**
 - Bulk electric system
 - Local transmission and sub-transmission
 - Distribution feeders and elements
 - Substations and components
 - Loads and resources

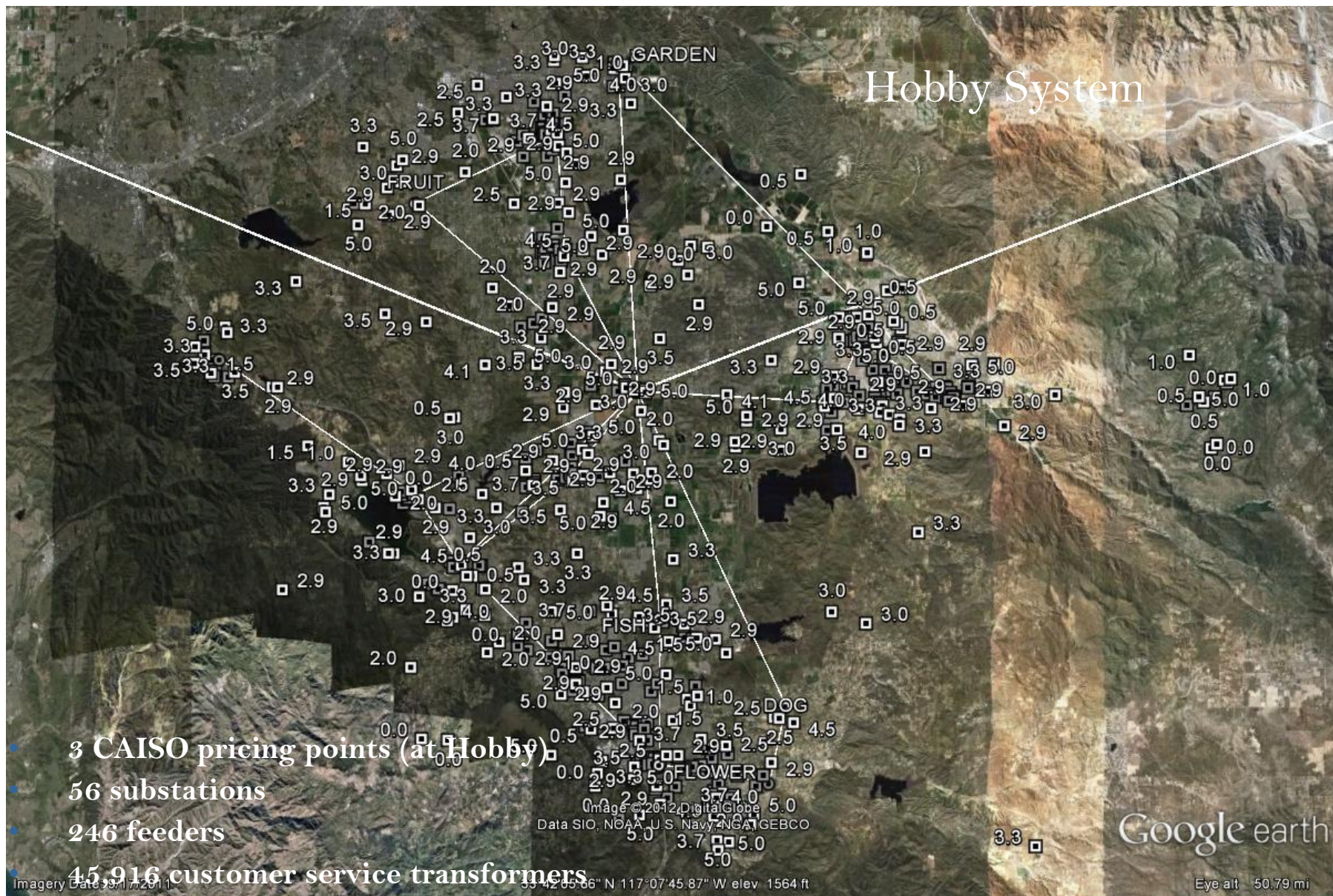
Nomenclature

- **Grid performance improvement (“benefit categories”):**
 - Reliability improvement (fewer, shorter outages)
 - Resiliency improvement (reduced exposure to major events)
 - Loss reduction (system efficiency)
 - Emission reduction, carbon reduction
 - Fuel diversity
 - Load relief (avoided or deferred infrastructure costs)
 - Reduced utility operating costs
 - Voltage violation relief
 - Power quality improvement
 - Expanded CVR opportunity
 - Incremental capacity (RA capacity, local RA capacity)
 - Incremental energy
 - Incremental ancillary services capacity
- **Demonstrable, directly attributable, quantifiable, priced**
- **If you can’t measure it and price it, it is not a real benefit**

Nomenclature

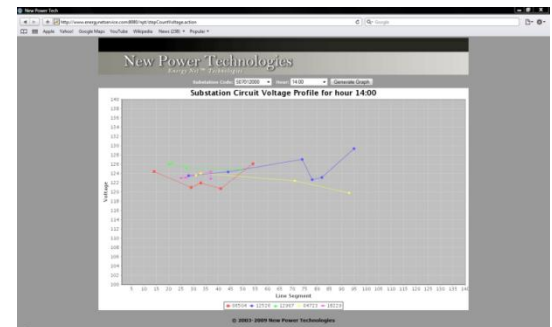
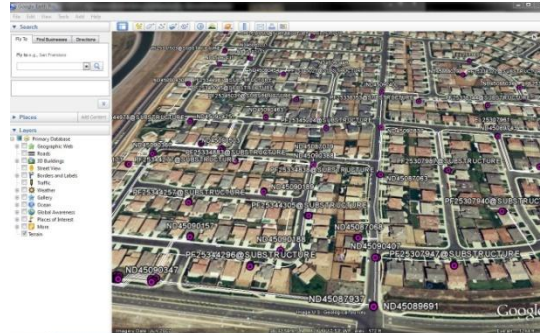
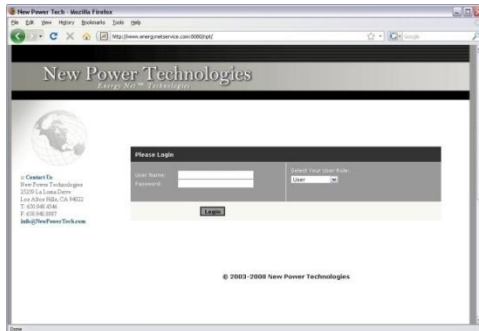
- **Pricing (valuing) network benefits:**
 - Direct, demonstrable result of one or more individual DERs
 - Avoids a [network operator] cost that will or would be incurred
 - Someone [customer] is willing to pay more
 - Economic damage function (VOS)
 - Location-specific
- **We are spending customers' money**





Energynet Platform

- Unified wide-area network model incorporating regional transmission, substations, distribution feeders
 - Allows direct representation of individual distributed generation, storage, loads, etc.
- Derived with software from existing legacy power system data
- Visualization, simulation and analytics
- Integrated GIS, field sensing/monitoring, customer metering, market data
- Web-based application platform



Why?

- **Visibility into grid conditions anywhere under any operating condition**
- **Accurate network representation of individual DER**
- **Direct observation of network interaction of DER – impacts and benefits**

Applications and Solutions

- **DG interconnection**
 - One-click evaluation
 - Regional low-impact site inventory
 - Regional impacts of intensive PV development
- **EV charging**
 - Network headroom, cluster identification
 - Managed charging – impact minimizing/value maximizing
- **Grid benefits of DG, DR, storage**
 - High-value DER identification
 - Identify DER that can offset otherwise necessary network expansion projects at lower cost
 - Network expansion project assessment
- **Regional reliability risk assessment**
- **Low-cost CVR opportunities**
- **Wide-area situational awareness with legacy sensors and monitors**

AB 327 DRP “Use Case” [from MTS WG]

- Expand the use of customer-side, distributed resources to...
 - provide local generation capacity needs (i.e., local RA capacity)
 - defer or avoid network infrastructure investments
 - provide safety benefits
 - provide reliability benefits
 - provide “other” grid savings or cost reductions
- Identify ‘optimal’ locations for DER deployment [to provide these benefits]
 - Direct relationship between individual DER projects and policy outcomes
 - Benefit-specific, location-specific, time/operating condition-specific
 - Aggregate capacity/size-specific
 - Local *and* system-level view

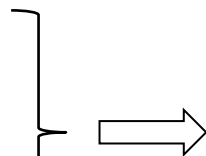
Energynet Optimal DER Portfolio Methodology

- Define an “optimal” portfolio of hypothetical individual DER projects that maximize grid benefits
 - Quantify the stack of grid benefits directly attributable to each project (i.e., network location)
 - Re-define the portfolio as conditions change
-
- The “location value of DER” is the value of *potential* grid benefits of an optimal DER project at that location
 - Procurement bogey
 - Incentives and/or contractual terms (business model-independent)

Optimal DER Portfolio Methodology

- **Optimal DER project characterization**

- Site location
- Type
- Size
- Operating profile
- Dispatchability
- Gross benefits and value



Procurement incentives and contractual terms

- **DER “loading order”**

1. Operational settings, load redistribution, capacitors
2. DR
3. DG
4. Storage

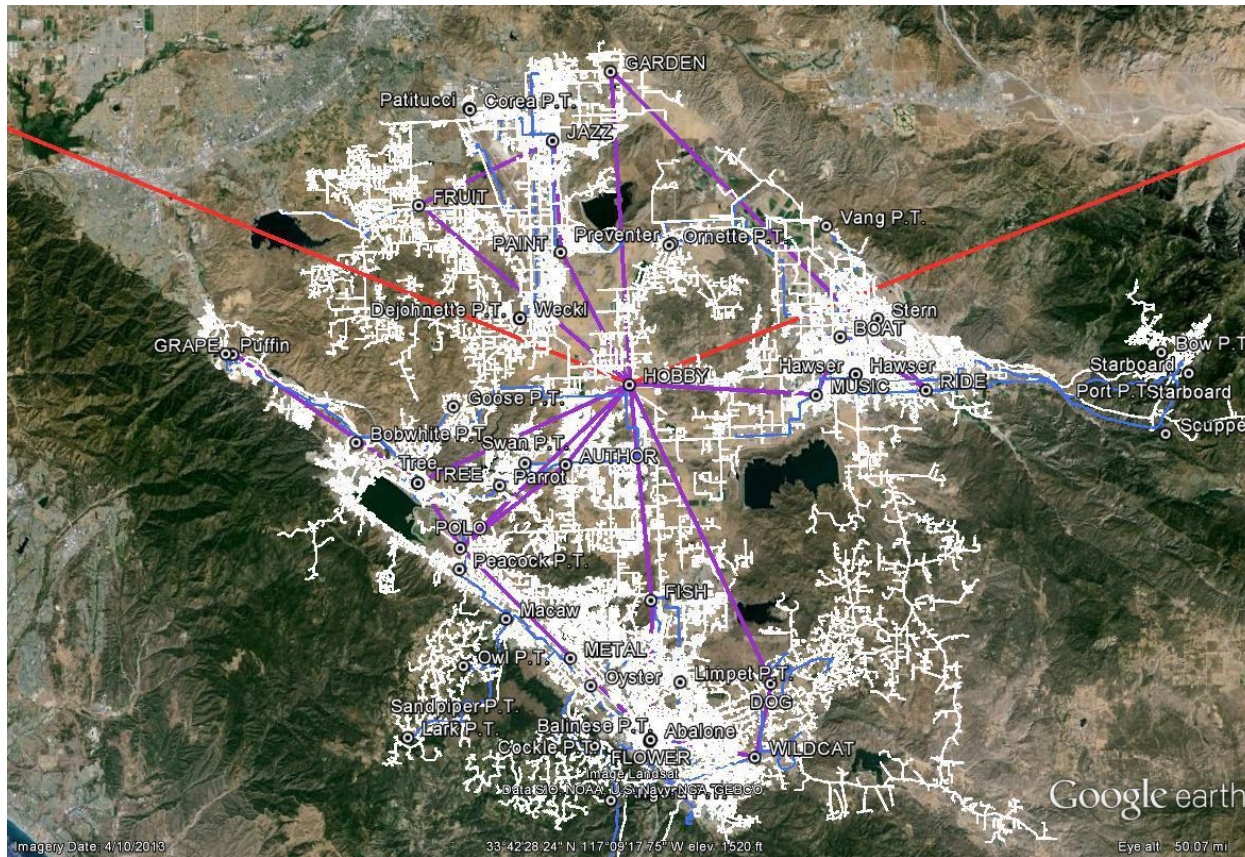
- **DER attributes defined by site host customer**

- **Build DER Portfolio**

- Maximize voltage and loss benefits [subject to non-export DG limits]
- Local overload relief, reliability enhancement, local capacity

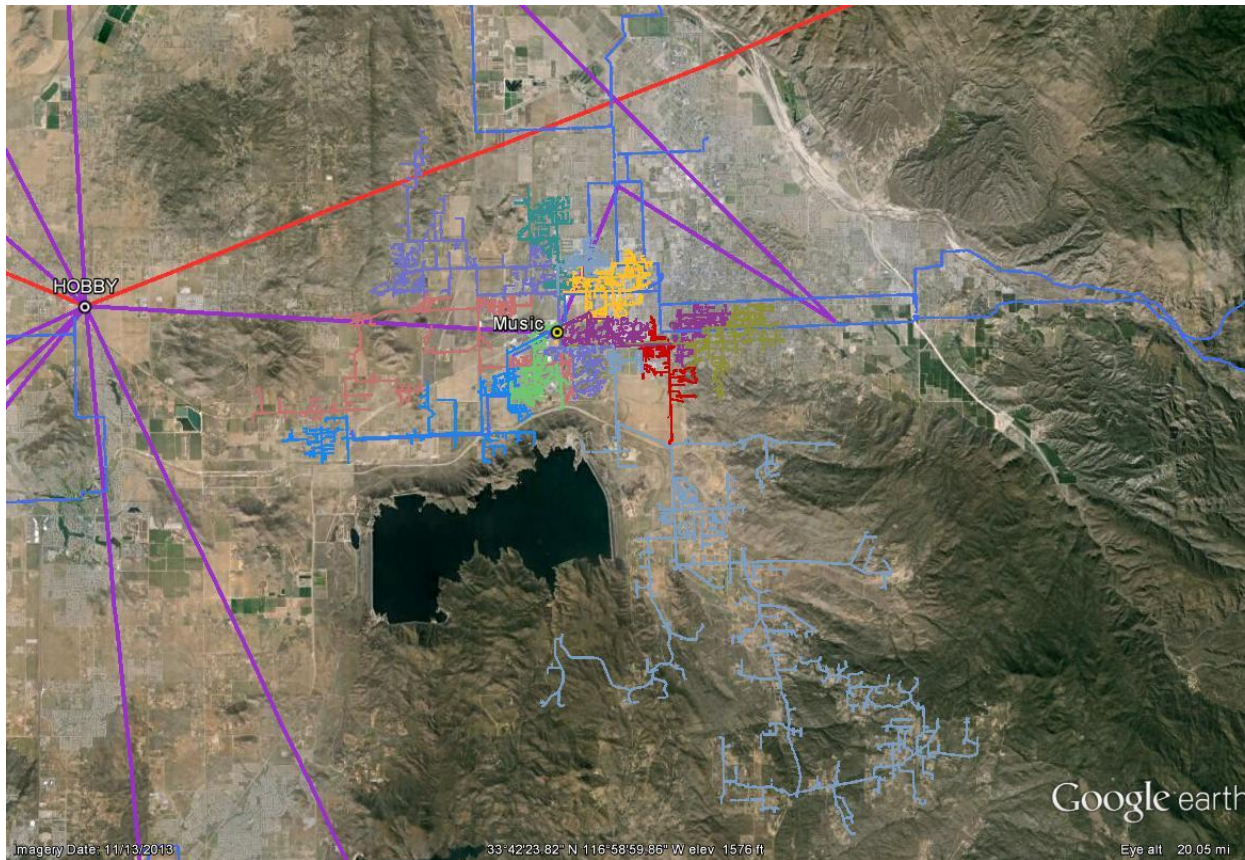
- **Annualized benefits derived from mapping of project operating profiles and varying system operating conditions**

“Hobby” System *Energynet* Optimal DER Portfolio



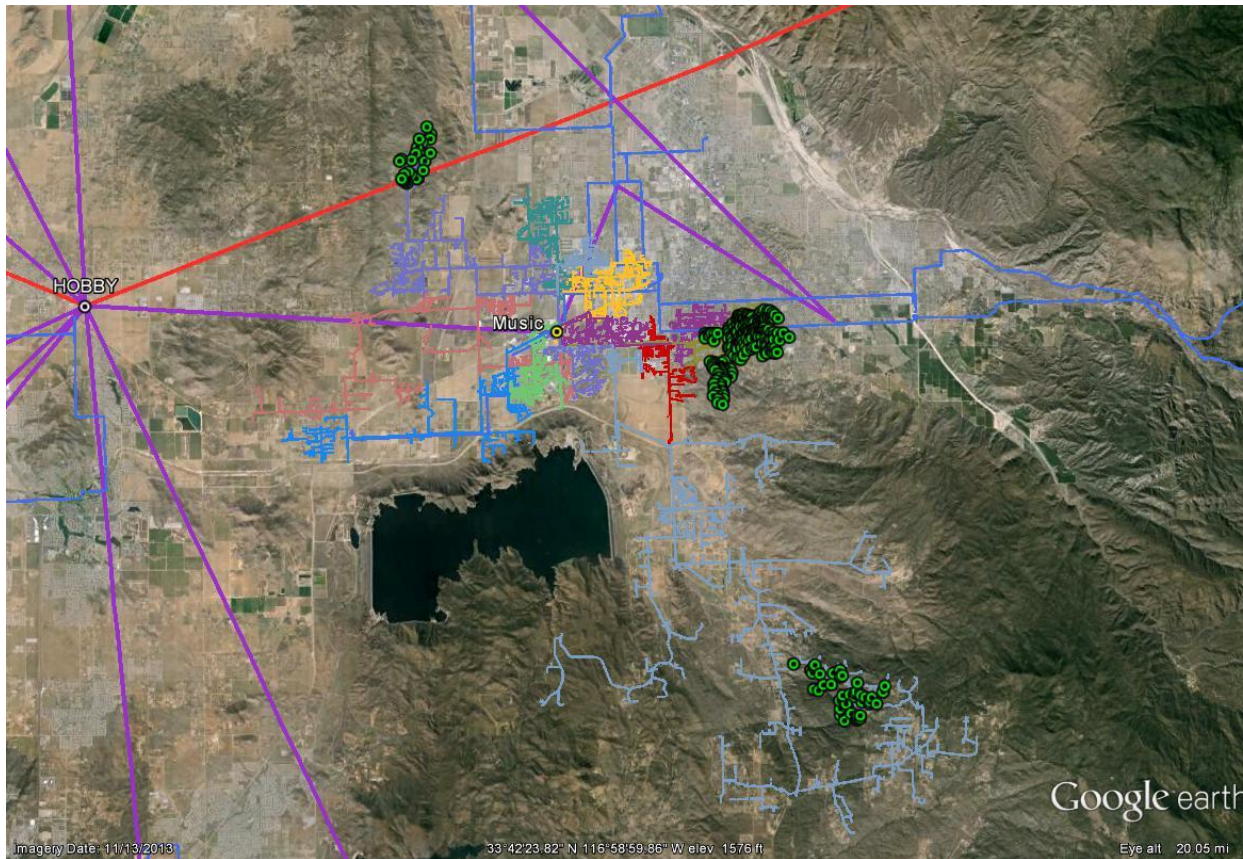
- Hypothetical DER projects analytically selected for maximum grid benefits, including overload relief and reliability improvement

Music Substation and Feeders



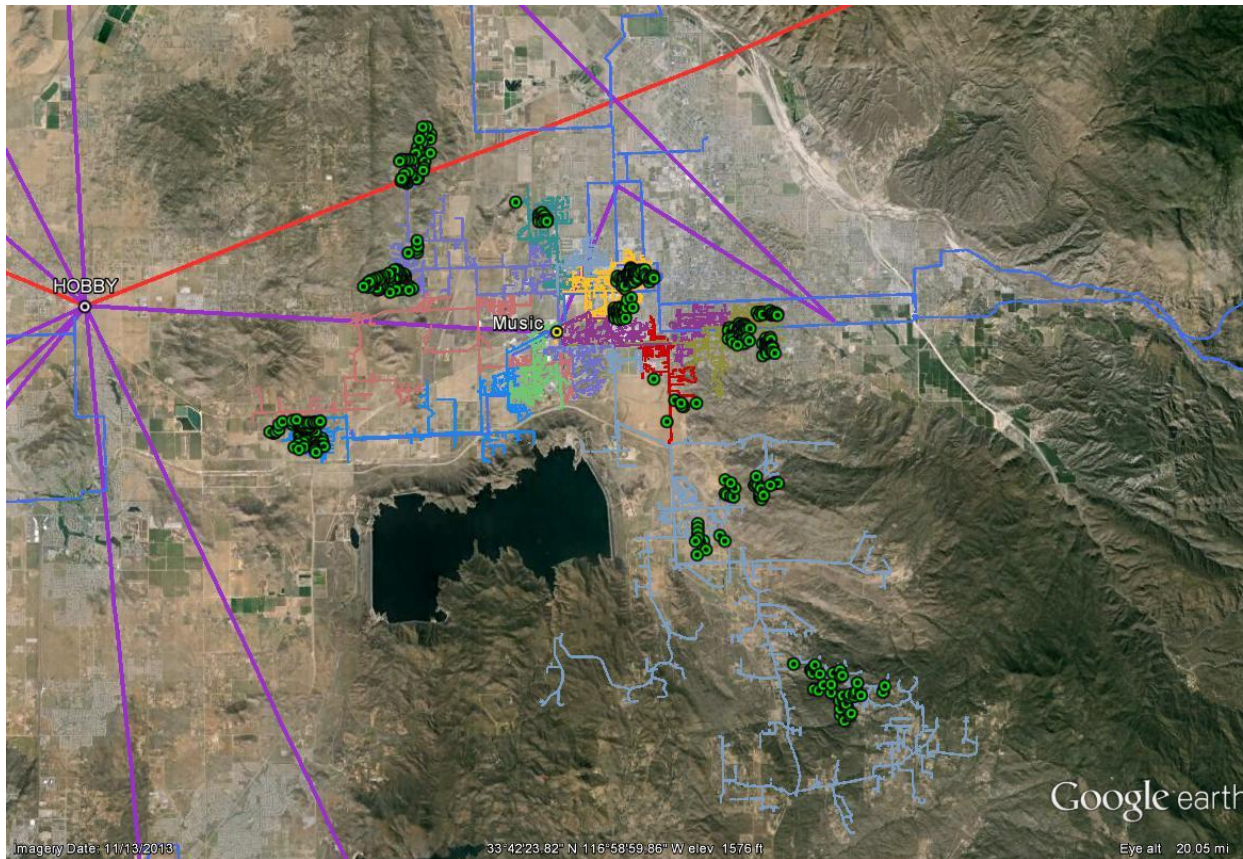
- 115/12 kV substation; 14 feeders

Music Substation DR



- Bias toward electrically remote, smaller sites

Music Substation DG



- Bias toward electrically remote, smaller sites, smaller DG projects

Music Substation Optimal DER Projects

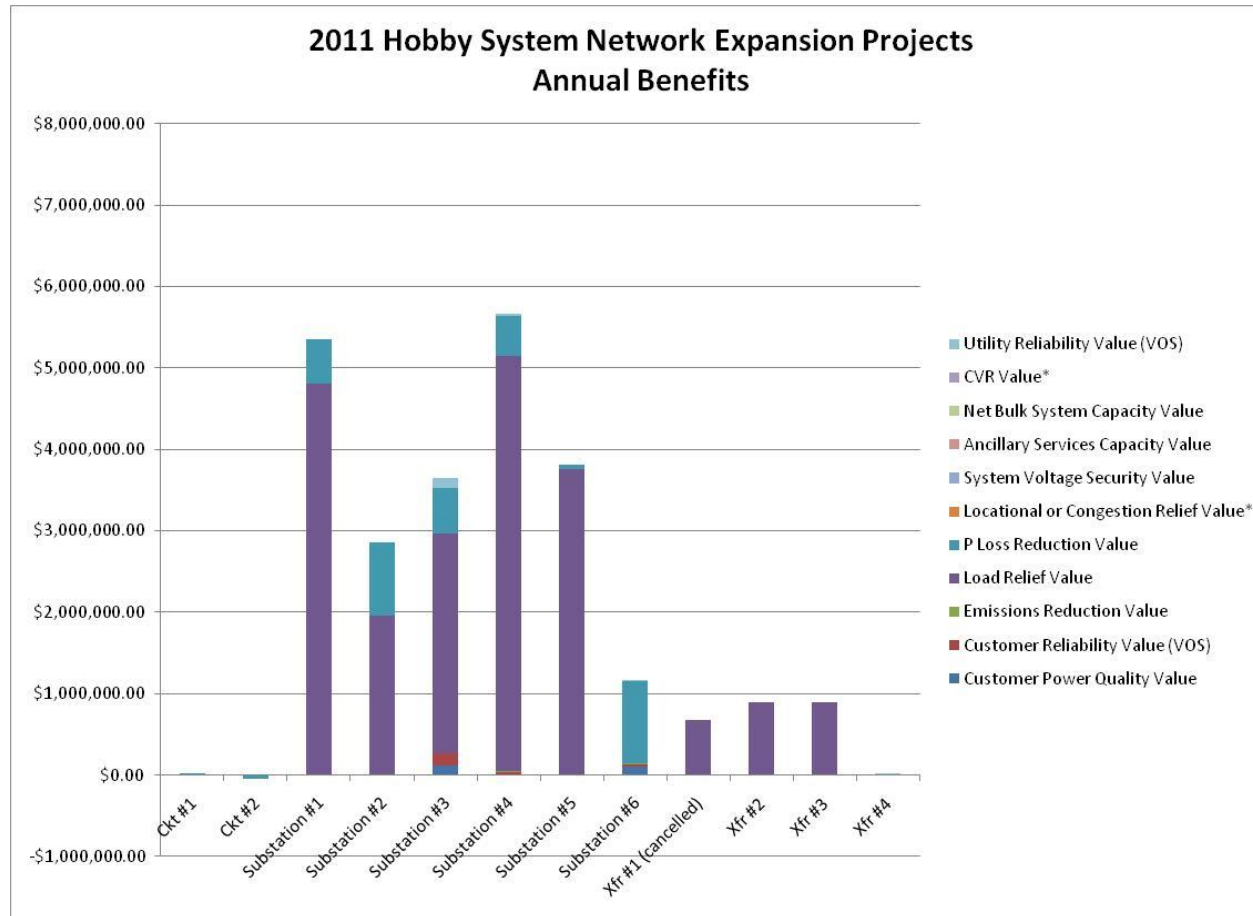
- **DR:**
 - 259 projects, 1.01 MW total
 - 97% residential and small business
- **DG:**
 - 327 projects, 4.927 MW total
 - 87.7% residential and small business, 12% medium business and ag, 1 industrial
- **Reduced reliability risk on three feeders**
- **Address 5.4 MW projected substation overload**
- **Loss reduction, voltage, and local capacity benefits**

Hobby System-wide Optimal DER Portfolio

- **DR: 3,000 projects on 55 feeders, 14.93MW total, 0.87% of load**
- **DG: 3,000 projects on 73 feeders, 46.86 MW total, 2.75% of load**
- **Loss reduction: 5.9 MW**
- **2.2% increase in system-wide minimum voltage**

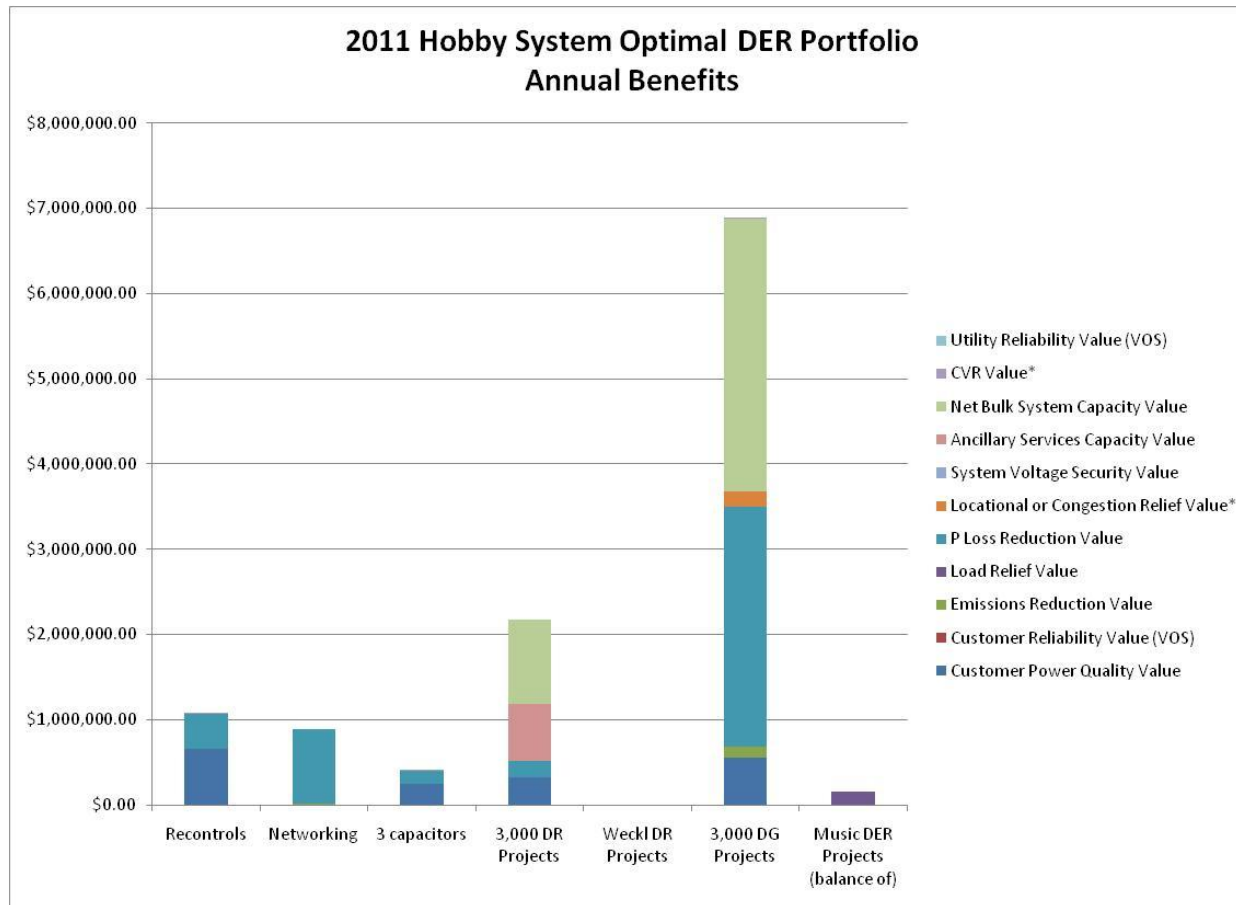
Note: voltage and loss optimization via GRIDfast analytics

Grid Benefits of Distributed Resources



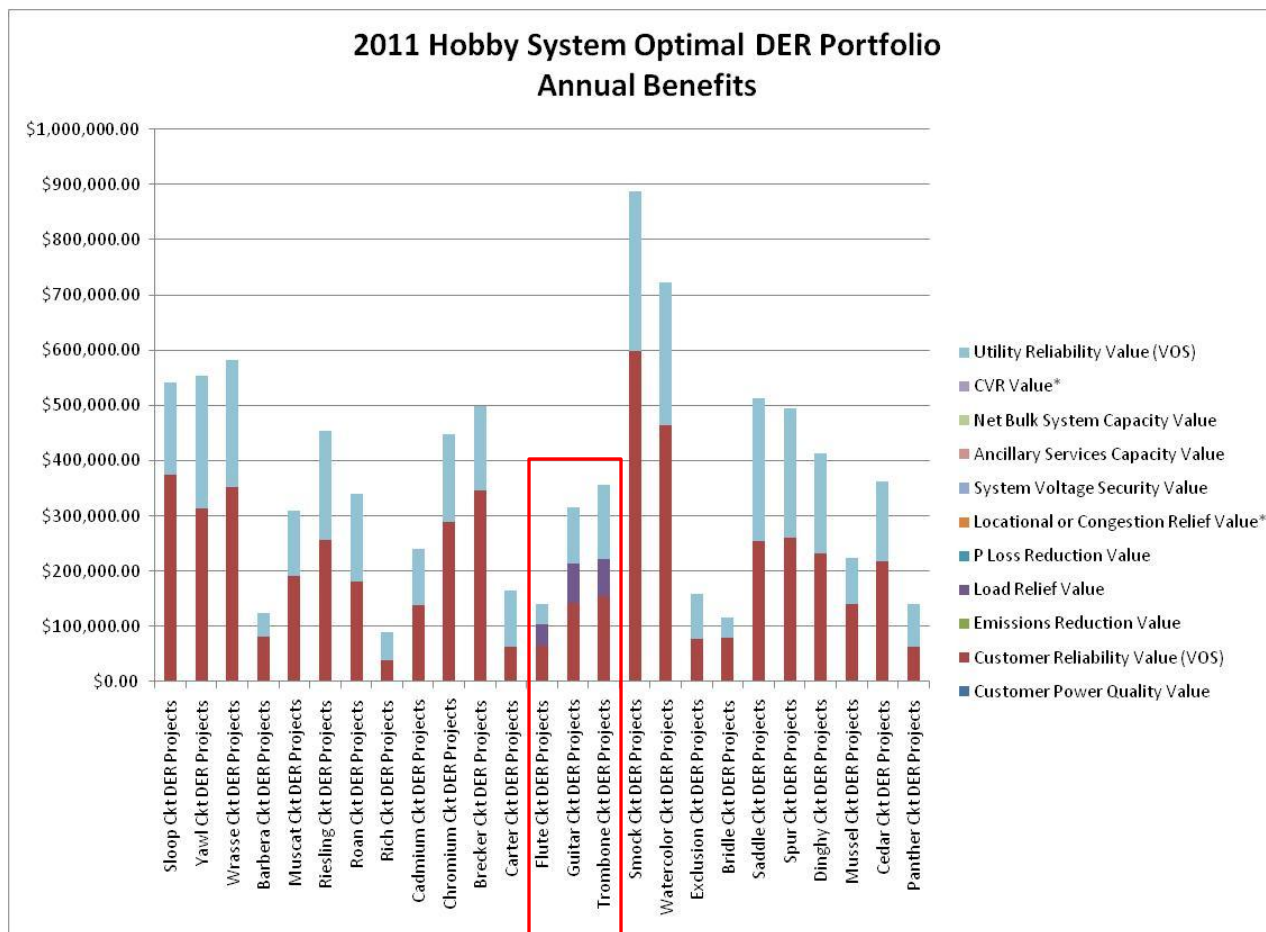
➔ Traditional network expansion project benefits are primarily in load relief

Grid Benefits of Distributed Resources



➔ Non-traditional projects can provide significant value, but in different categories, *e.g.* local capacity, loss reduction and CVR.

Grid Benefits of Distributed Resources



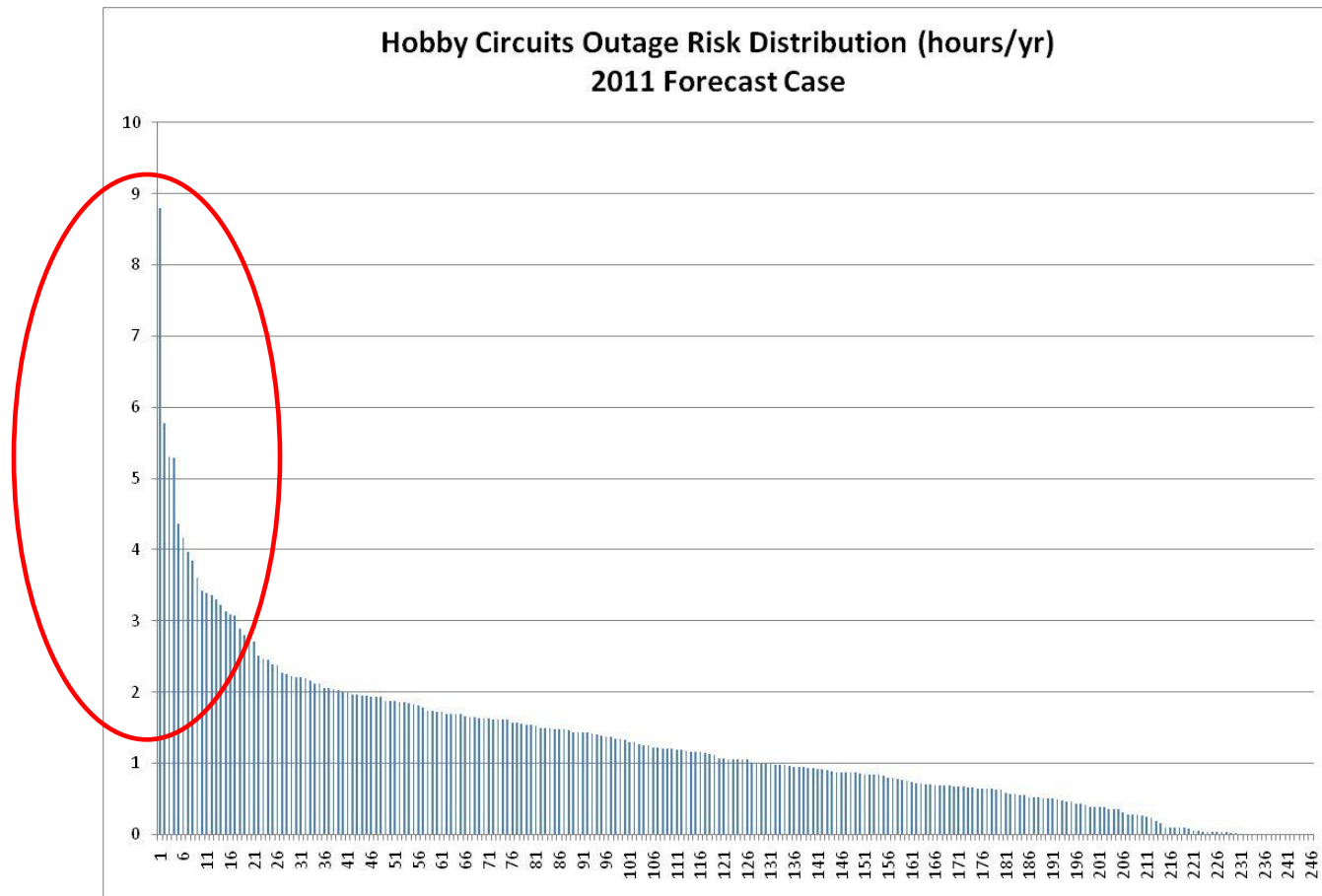
➔ Certain DER projects on certain feeders yield significant value, primarily due to reliability improvement.

Grid Benefits of Distributed Resources

- Sample result: four optimal portfolio DG projects at different locations in one feeder
- Different size, type, operating profile, and total value of benefits for each “network location”

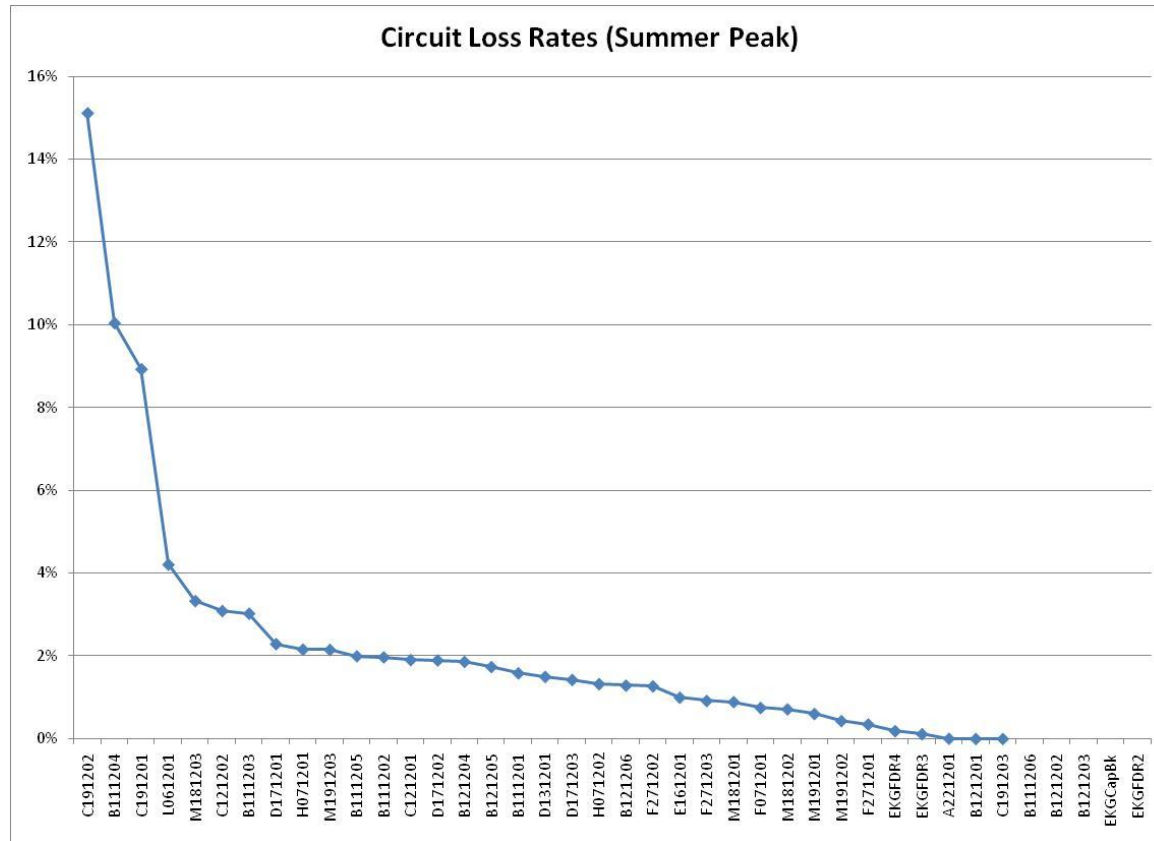
| BUS_ID | Project Description | Max MW | Max MVAR | Non-PV Dispatch Profile | Summer Peak Voltage Benefit | Off Peak Voltage Benefit | Total P Loss Value (\$/yr) | Total Energy Value (\$/yr) | Total Congestion/Location Value (\$/yr) | Total Bulk Capacity Value (\$/yr) | Total Emission Reduction Value (\$/yr) |
|--------------------|---|--------|----------|-------------------------|-----------------------------|--------------------------|----------------------------|----------------------------|---|-----------------------------------|--|
| Bus_15462_2289825E | Residential PV 6.5 kW | 0.0065 | 0 | | yes | - | 537 | 3,180 | 32 | 778 | 32 |
| Bus_15462_2289826E | Residential PV 1.5 kW | 0.0015 | 0 | | yes | - | 176 | 734 | 7 | 179 | 7 |
| Bus_15462_2289826E | Residential PV 3 kW | 0.003 | 0 | | yes | - | 1,420 | 1,468 | 15 | 359 | 21 |
| Bus_15462_2289827E | Residential PV 5.5 kW | 0.0055 | 0 | | yes | - | 1,199 | 2,691 | 27 | 658 | 30 |
| Bus_15462_P5466675 | Medium Business Synchronous Off-Peak 238.2 kW | 0.2382 | 0.1191 | Off-Peak | - | yes | 1,549 | 46,672 | - | 2,897 | 25 |

Feeder-level Reliability Risk



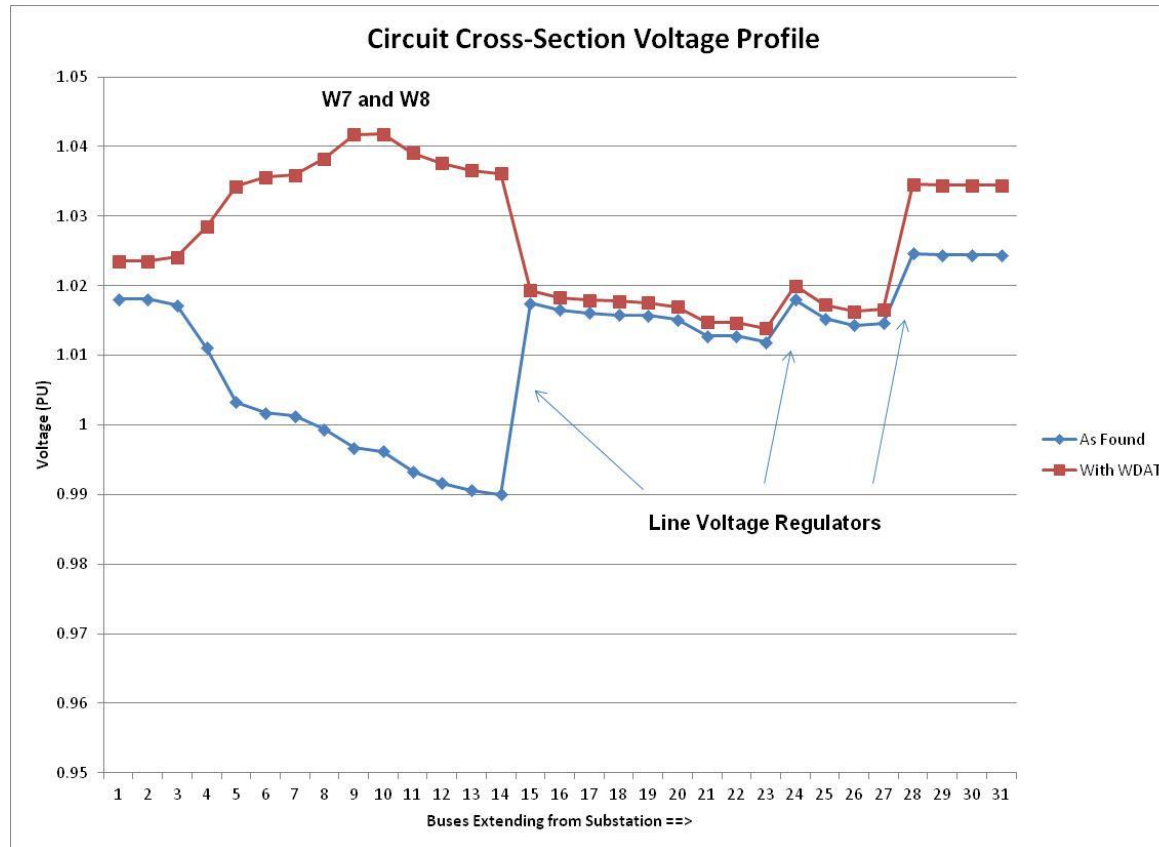
➔ Targeted DER can reduce reliability risk of those feeders most vulnerable to random contingencies.

Feeder-level Losses



➔ Targeted DER can reduce losses on high-loss feeders

Feeder Voltage Profile and CVR



➔ Targeted DER can flatten feeder voltage profile, enabling more extensive CVR

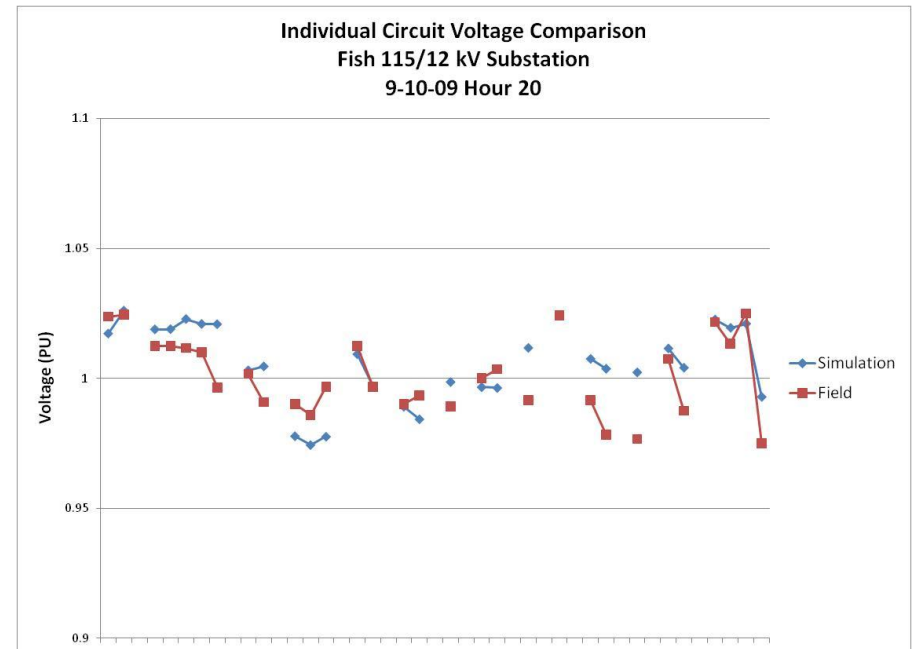
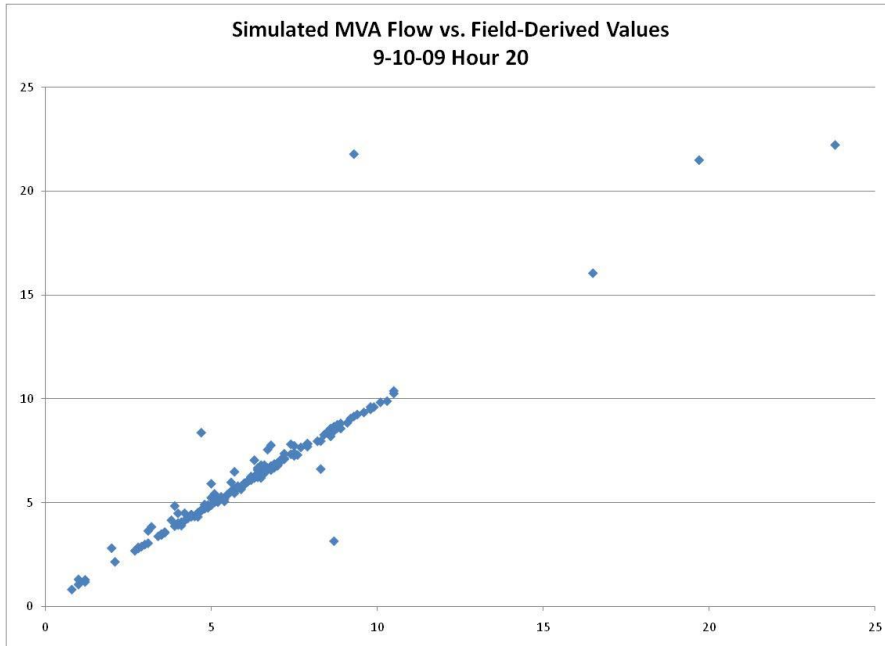
Illustrative Potential DER Benefits

| | Large (250-feeder) utility system | |
|------------------------------------|-----------------------------------|----------------------|
| | Network Operator Benefits | Customer Benefits |
| Loss reduction | \$28/yr per customer | |
| Reduced energy to serve load (CVR) | \$18/yr per customer | |
| Improved reliability | \$20/yr per customer | \$13/yr per customer |
| Avoided marginal capital projects | \$68 per customer/10 yrs | |
| Improved power quality | | \$7/yr per customer |

Relevant Findings on Beneficial DER

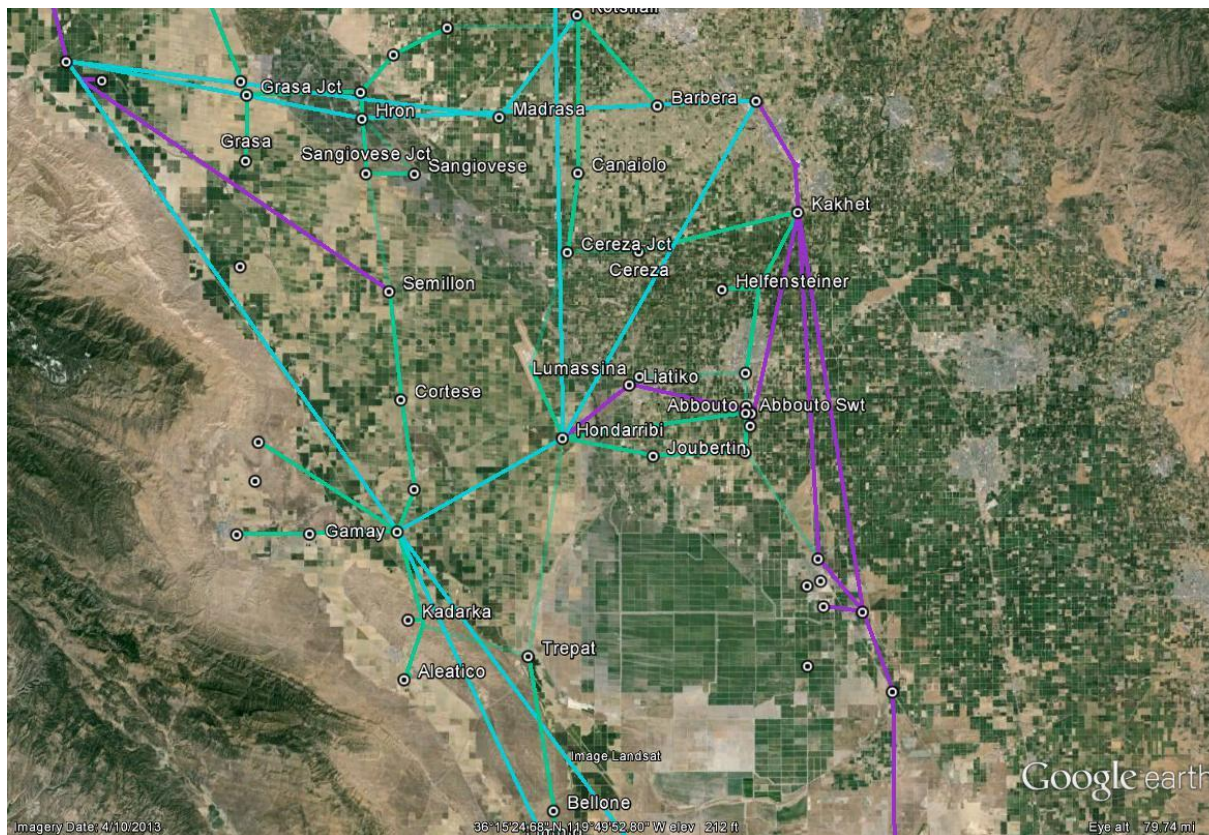
- **DER can benefit power delivery system performance.**
- **DER project location and attributes matter. A lot.**
- **Beneficial DER projects can be identified and potential benefits rigorously quantified and valued.**
- **Benefits that persist over many operating conditions/hours yield more value**
- **DER projects providing multiple benefits yield more value**
- **Beneficial DER changes with real additions and changing conditions. Plan to re-assess often.**

Energynet Simulation a Validated Predictor of Actual System Conditions



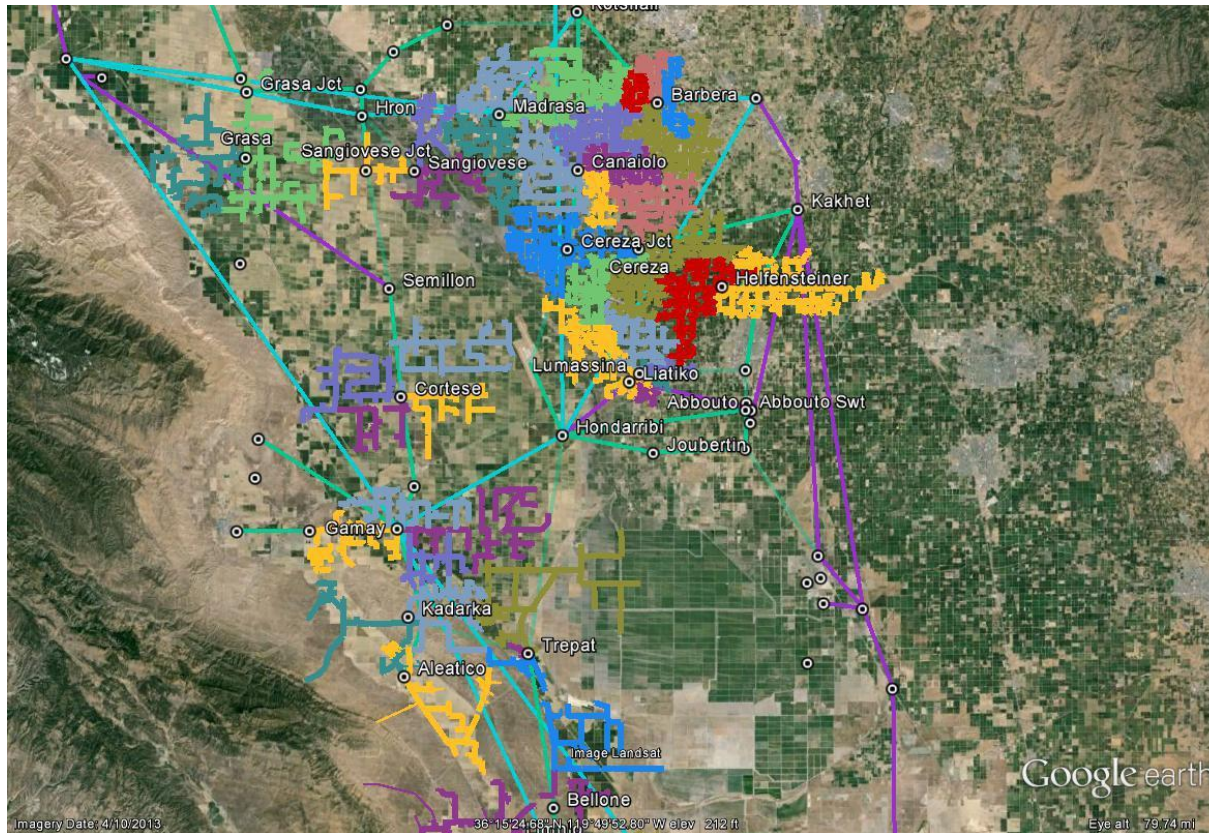
- Simulation voltage results within 2% of field data reads at ~650 widely-dispersed locations
- Area model produced from raw legacy utility data in one month
- Area model updated in one day via secure web file transfer

“Vineyard” Regional Transmission



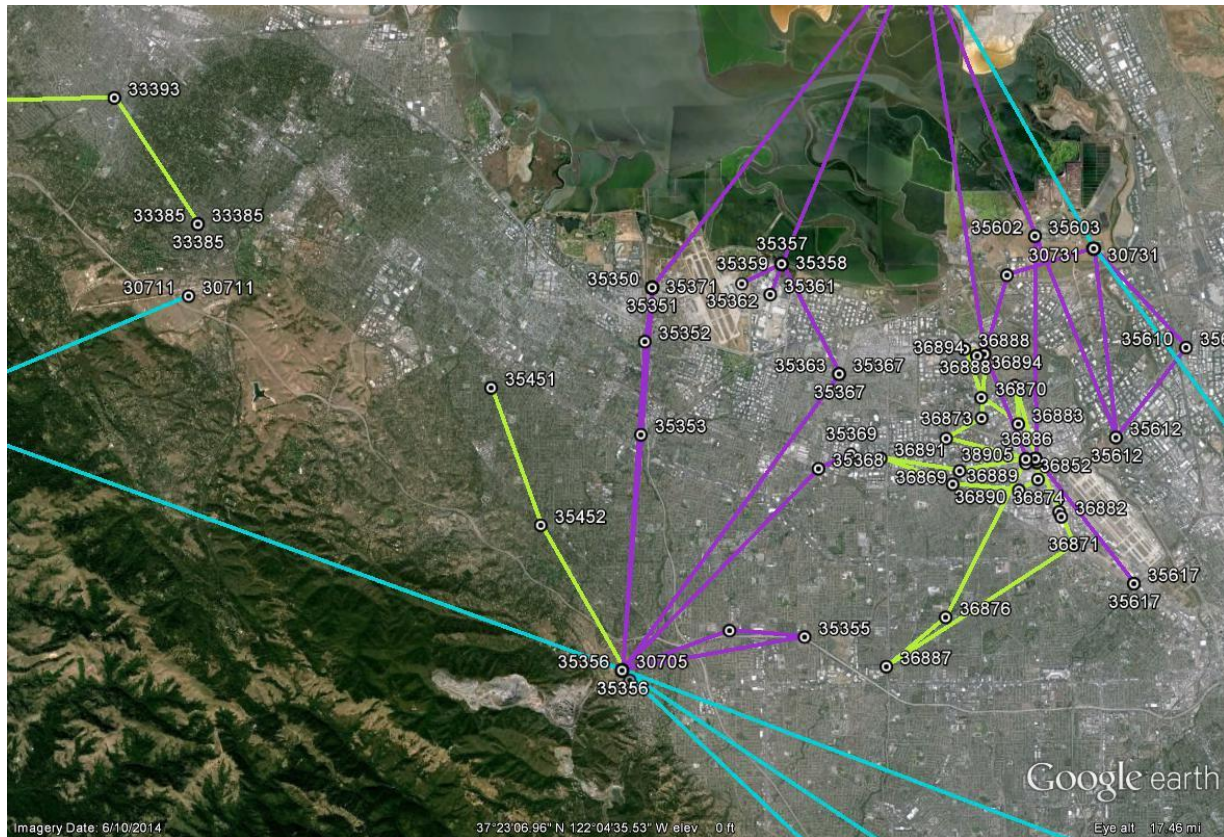
- 230 kV
- 115 kV
- 70 kV

“Vineyard” *Energynet*



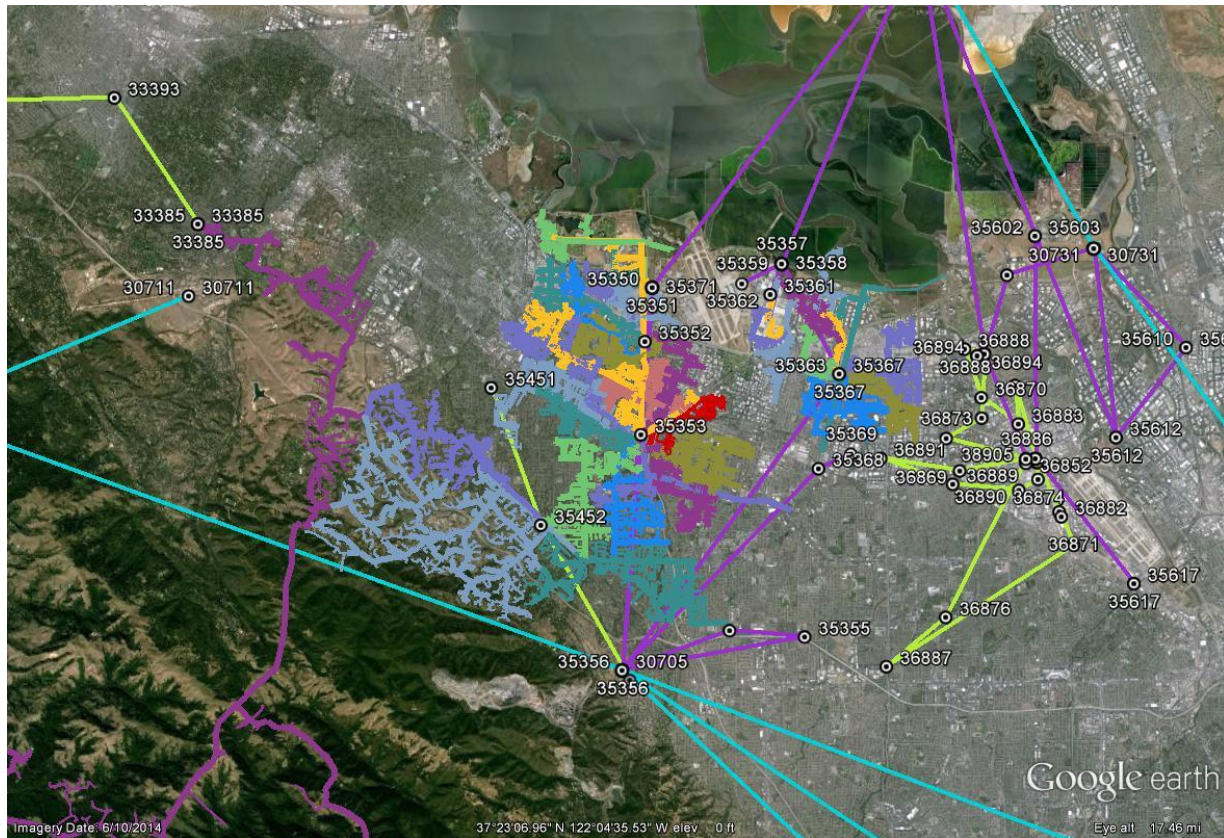
- 26 substations
- 51 distribution feeders (12kV and 21 kV)
- 5 DPAs

“Peninsula” Regional Transmission



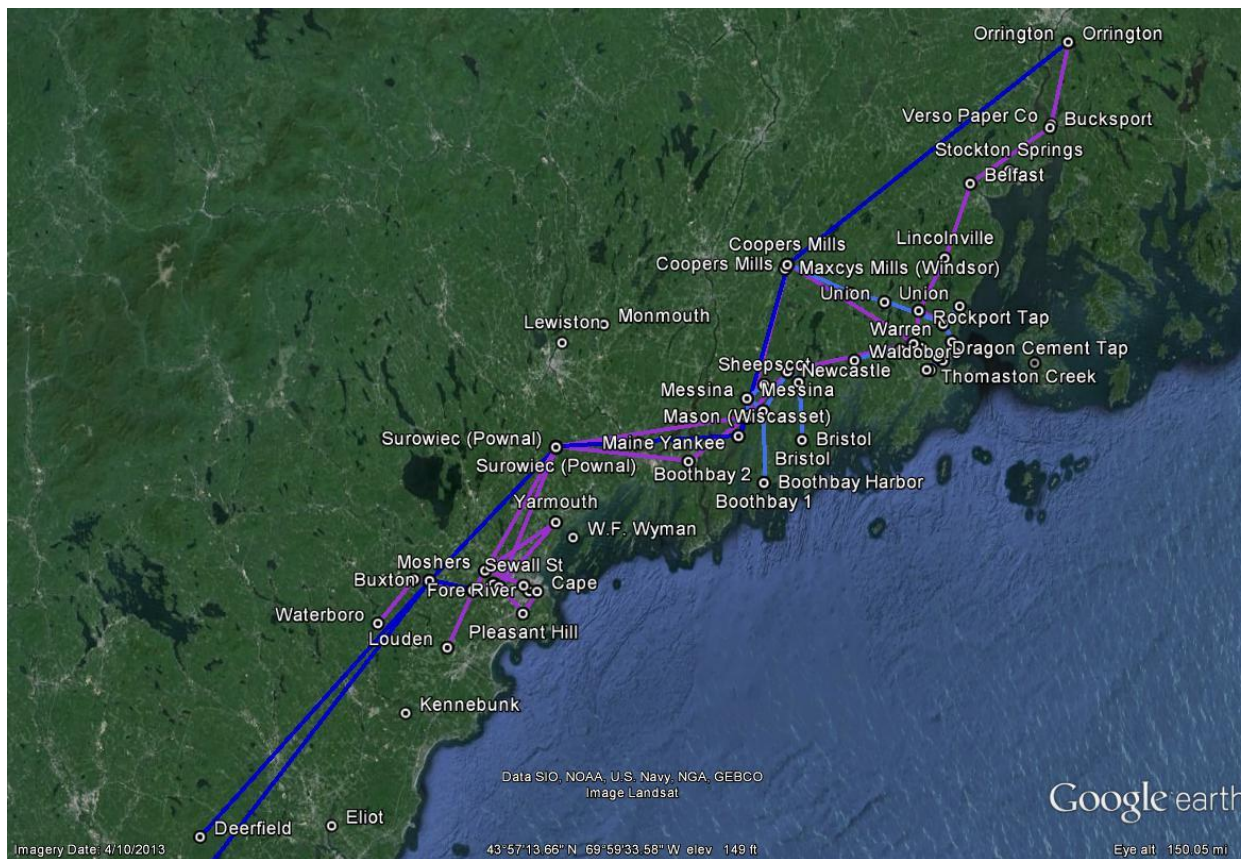
- 230 kV
- 115 kV
- 60 kV

“Peninsula” *Energynet*



- 11 substations (58 CAISO pricing nodes)
- 41 distribution feeders

Maine Power System

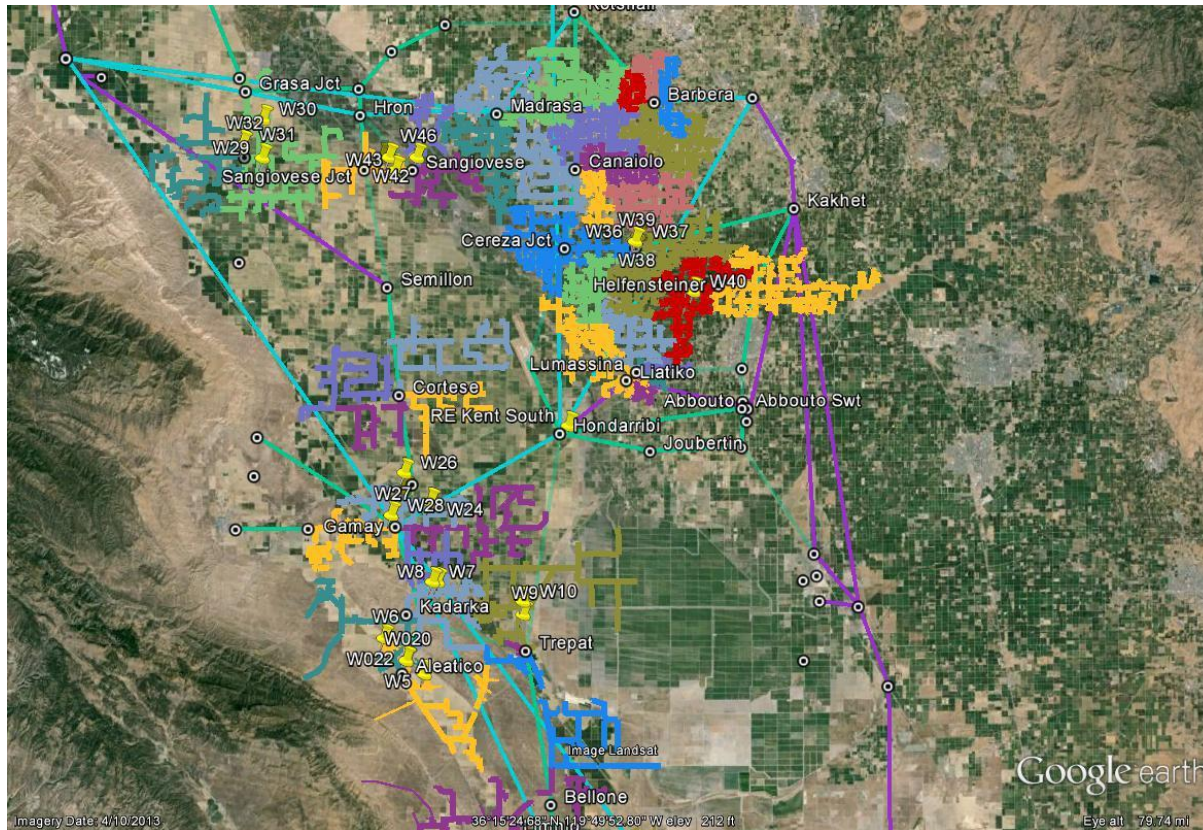


- 345 kV
- 115 kV
- 34.5 kV

Energynet Deployments

- **SMUD**
 - > 750 feeder integrated T&D model commercial deployment
 - DG Siting, EV Charging, GRIDplan DER apps
 - Elk Grove #1 system (competitive commercial pilot, 2010)
- **PG&E**
 - “Vineyard” system (51 feeder integrated T&D simulation)
 - Regional impacts of high PV penetration (CEC)
 - 5 circuits; high EV penetration area (LAHFT)
 - EV Charging app (2012)
- **Southern California Edison**
 - “Hobby” system (246 feeder integrated T&D simulation)
 - “Mountain” system (190 feeder integrated T&D simulation)
 - Full-scale demonstration; simulation validation (2004-2009)
 - Legacy sensors for a wide-area monitoring network and situational awareness
 - DG Siting app (2010)
- **Silicon Valley Power**
 - 48 feeder integrated T&D simulation; proof of concept demonstration (2003-2005)

Vineyard Wholesale PV Evaluation

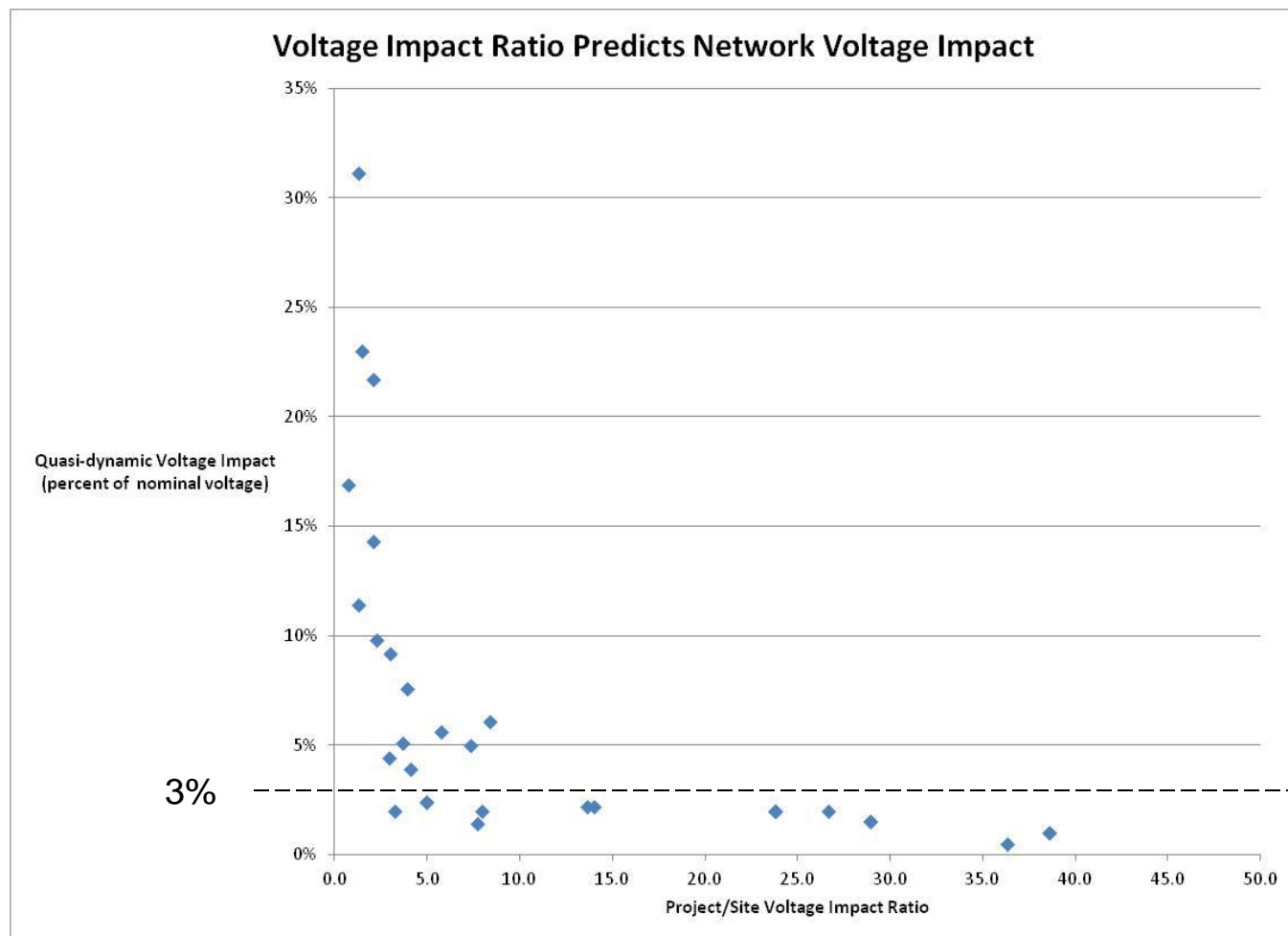


- Regional impacts of DER (PV in this case) at high “penetration” levels
- 46 individual distribution-connected wholesale PV projects
- Approx. 80 transmission-connected PV projects

Findings on Feeder DER “Integration Capacity”

- Wholesale PV development can and does result in “penetration” far exceeding 15% of load.
- Feeder export, transformer reverse flow and transmission reverse flow (i.e., local generation *exceeding* local load) are common.
- Reverse flow may impact the function of certain devices.
- Feeder voltage impacts of variable generation are modest as long as interconnections are not “weak.”
- System voltage impacts are also damped by distribution feeder voltage management
- Potential for feeder and substation transformer overload under light load or loss of load.

“Stiff” Locations Limit System Voltage Impacts of Variable PV Output



Voltage Impact Ratio = Utility Source SC (MVA) @ PCC ÷ Project Rated Output (MVA)

Conclusion

- DRPs can incorporate rigorous quantification and valuation of direct grid benefits of DER in a broad range of benefit categories by location.
- DRPs incorporating DER as a system resource can have regional scope (many substations and DPAs) and full feeder element detail.
- Representing DER as connected within their feeders reveals their full impacts and grid benefits.
- Not all DER is grid-beneficial.
 - Location-specific
 - Size and characteristic - attribute-specific
 - Operational alignment with grid conditions
- Distribution feeders can accommodate DG as a significant share of load – with attention to interconnection sites and network characteristics.

Supplemental Slides

DG Site Evaluation App – 3 MW PV on 12 kV Feeder

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DG Site Evaluation | EV Charging Evaluation | GRIDplan DER

Site Information

Line Feature ID: 26000355

Size (kW): 3000

Bus ID : Bus_M181201_ND45286966
Line Feature ID : 26000355
Bus Number : 839902
Circuit Number : M181201
Type : UG
Phases : 3.0
Neutral : #na
Sum X/R : 2.349752306392144
Min Rating MVA : 4.0
OK Automated Capacitors : 2
Circuit Min Daytime Load MW :
Non Export Limit kW :
Substation Code : M18TX16912
Voltage Impact Ratio : 41.83466942790821

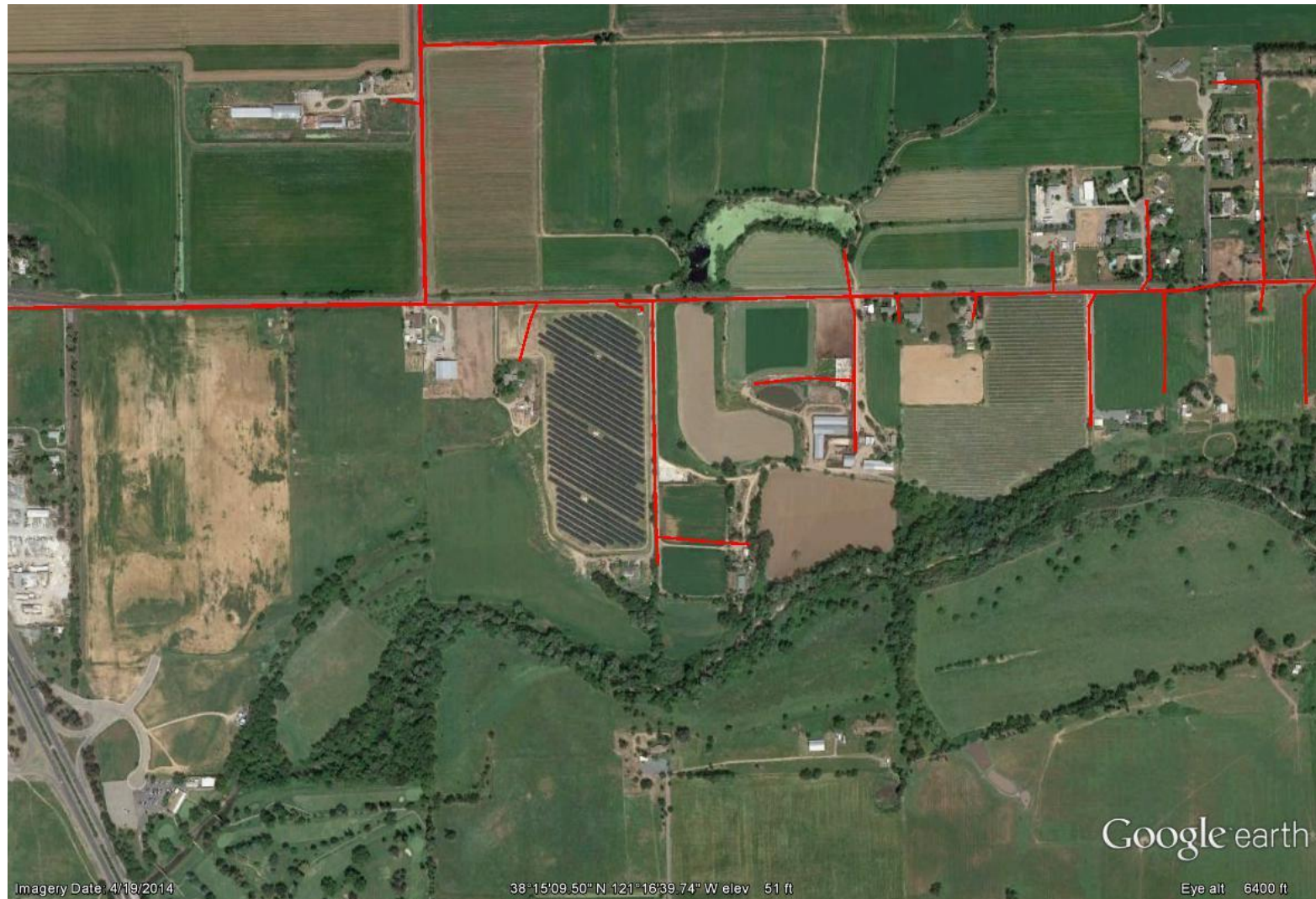
| Transformer ID | MVA | LTC Enabled | Reg Bus # |
|----------------|------|-------------|-----------|
| M18TX16912 | 20.0 | 0 | |

Get Info

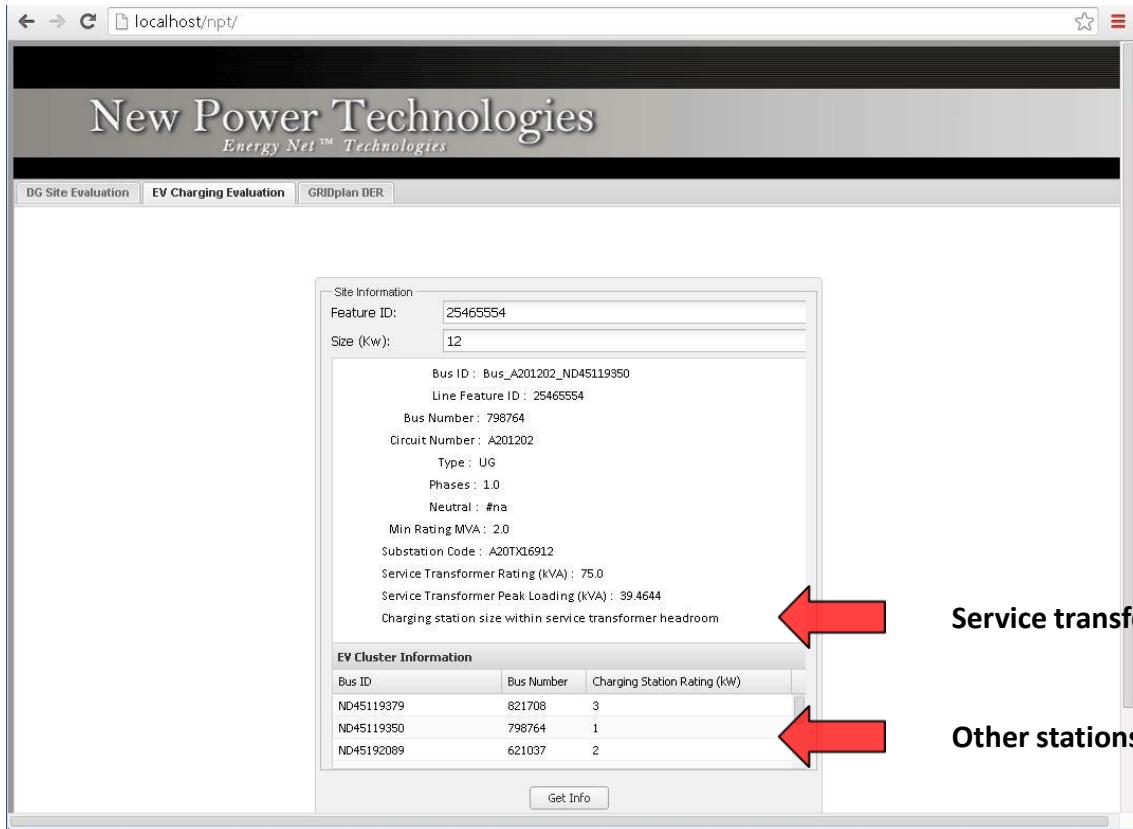
- **> feeder non-export limit**
 - Total PV = 119% of feeder connected load
- ✓ **< min upstream line rating**
- ✓ **3 ϕ location**
- ✓ **Feeder voltage regulation**
- ✓ **Voltage Impact Ratio > 20**
- ✓ **Max voltage impact: 1%**

➤ **Site-specific, multi-variable assessment in one click**

DG Site Evaluation App – 3 MW PV on 12 kV Feeder



Energynet EV Evaluation App



The screenshot displays the 'EV Charging Evaluation' tab of the Energynet EV Evaluation App. The 'Site Information' section shows the following details:

- Feature ID: 25465554
- Size (Kw): 12
- Bus ID: Bus_A201202_ND45119350
- Line Feature ID: 25465554
- Bus Number: 798764
- Circuit Number: A201202
- Type: UG
- Phases: 1.0
- Neutral: #na
- Min Rating MVA: 2.0
- Substation Code: A20TX16912
- Service Transformer Rating (kVA): 75.0
- Service Transformer Peak Loading (kVA): 39.4644
- Charging station size within service transformer headroom

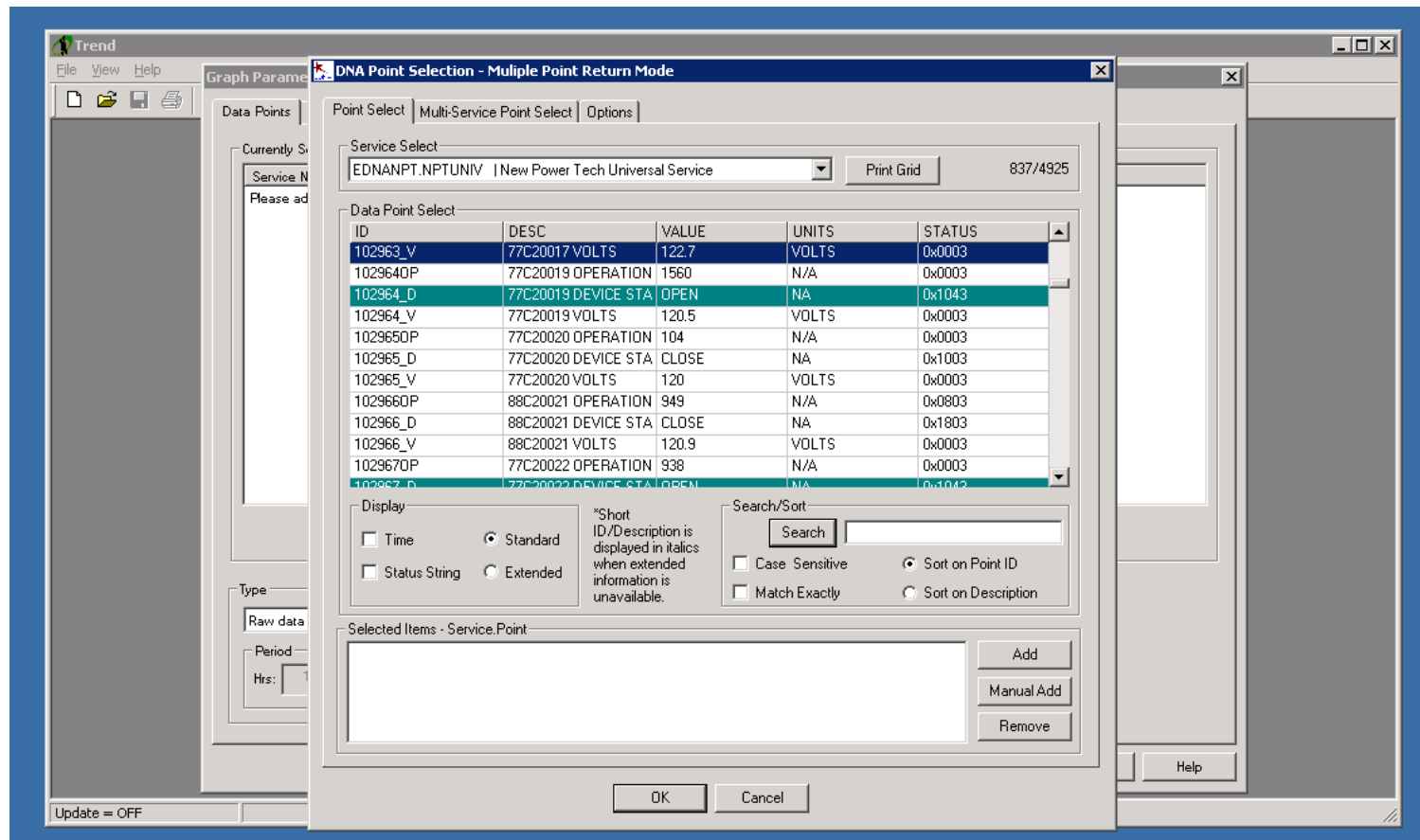
Below this, the 'EV Cluster Information' table lists other stations in the cluster:

| Bus ID | Bus Number | Charging Station Rating (kW) |
|------------|------------|------------------------------|
| ND45119379 | 621708 | 3 |
| ND45119350 | 798764 | 1 |
| ND45192089 | 621037 | 2 |

Two red arrows point from the text labels to the table. The first arrow points to the first row (ND45119379) and is labeled 'Service transformer headroom'. The second arrow points to the second row (ND45119350) and is labeled 'Other stations in cluster'.

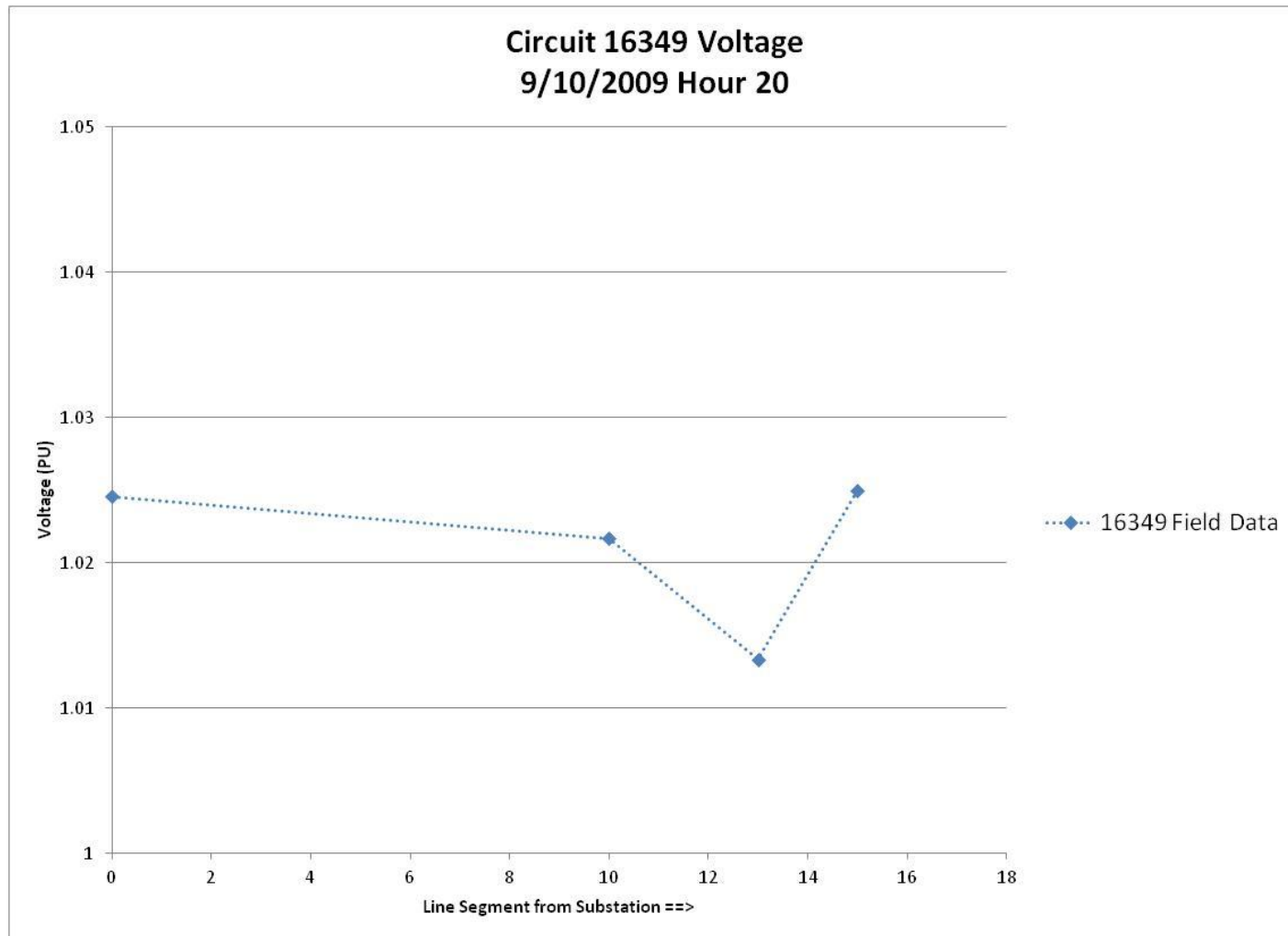
- Charging station site assessment in one click

Turning data into situational awareness: Legacy Data

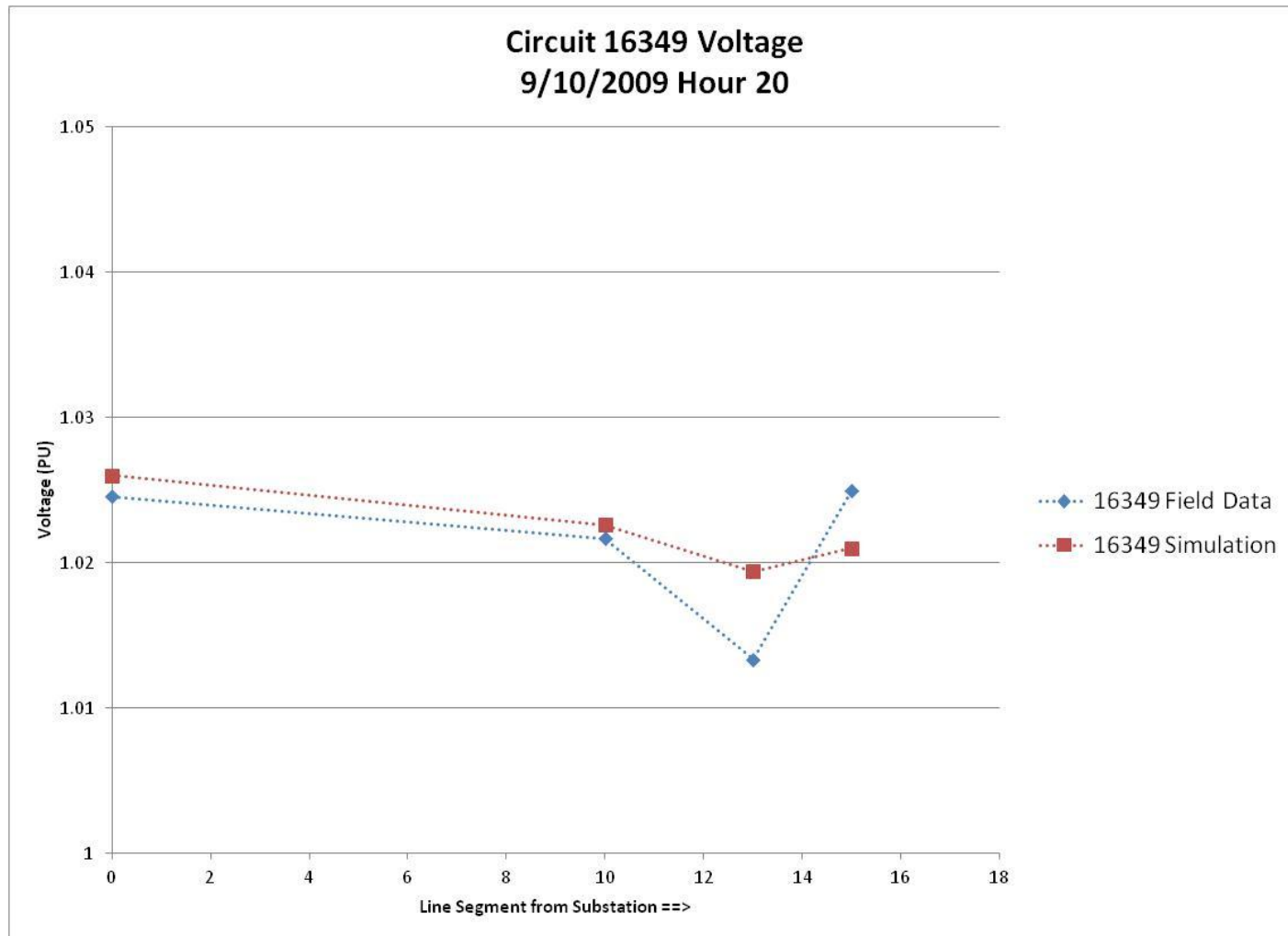


Existing tabular data without topological cues

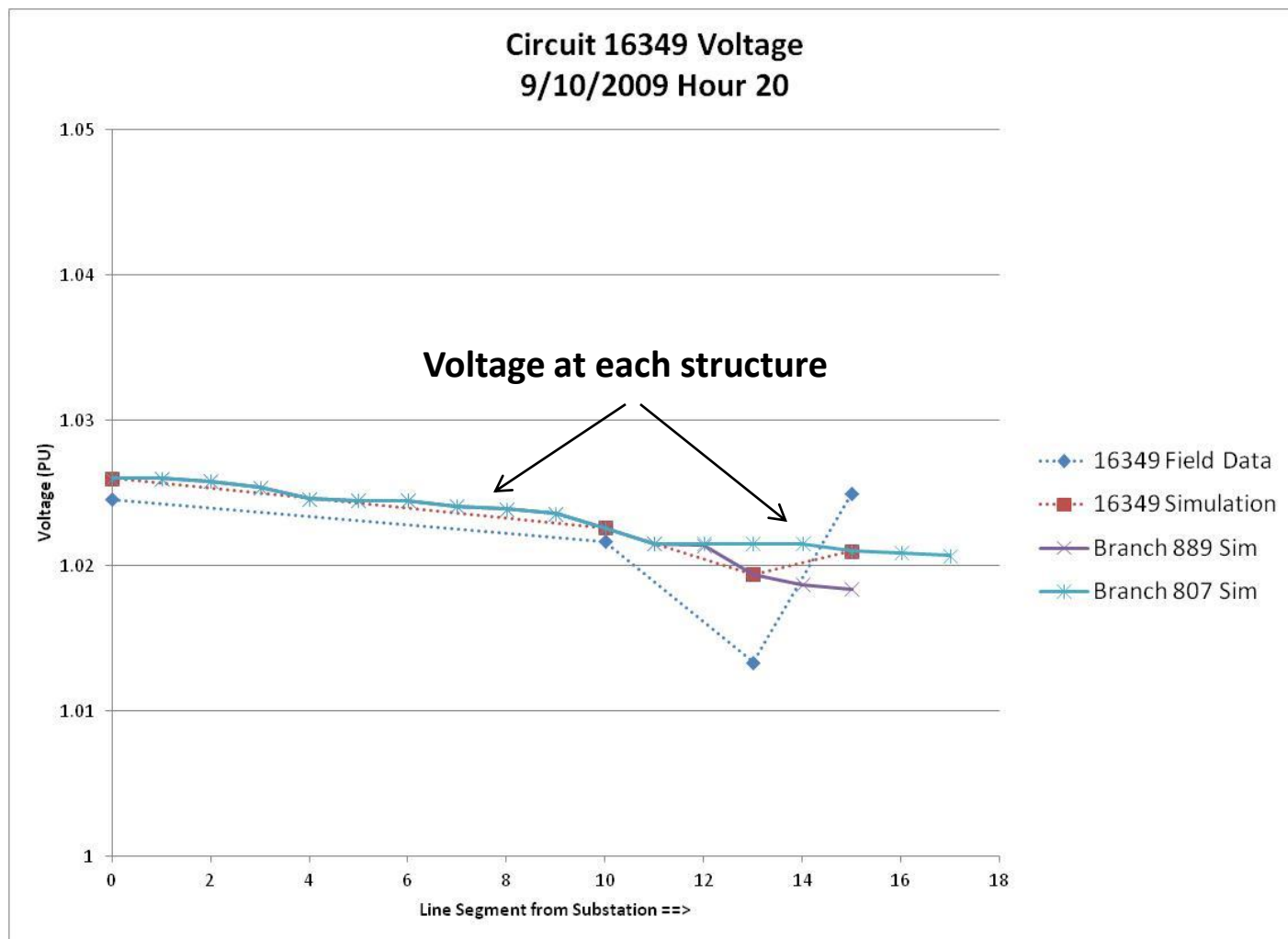
Turning data into situational awareness: => Field Circuit Voltage Profile



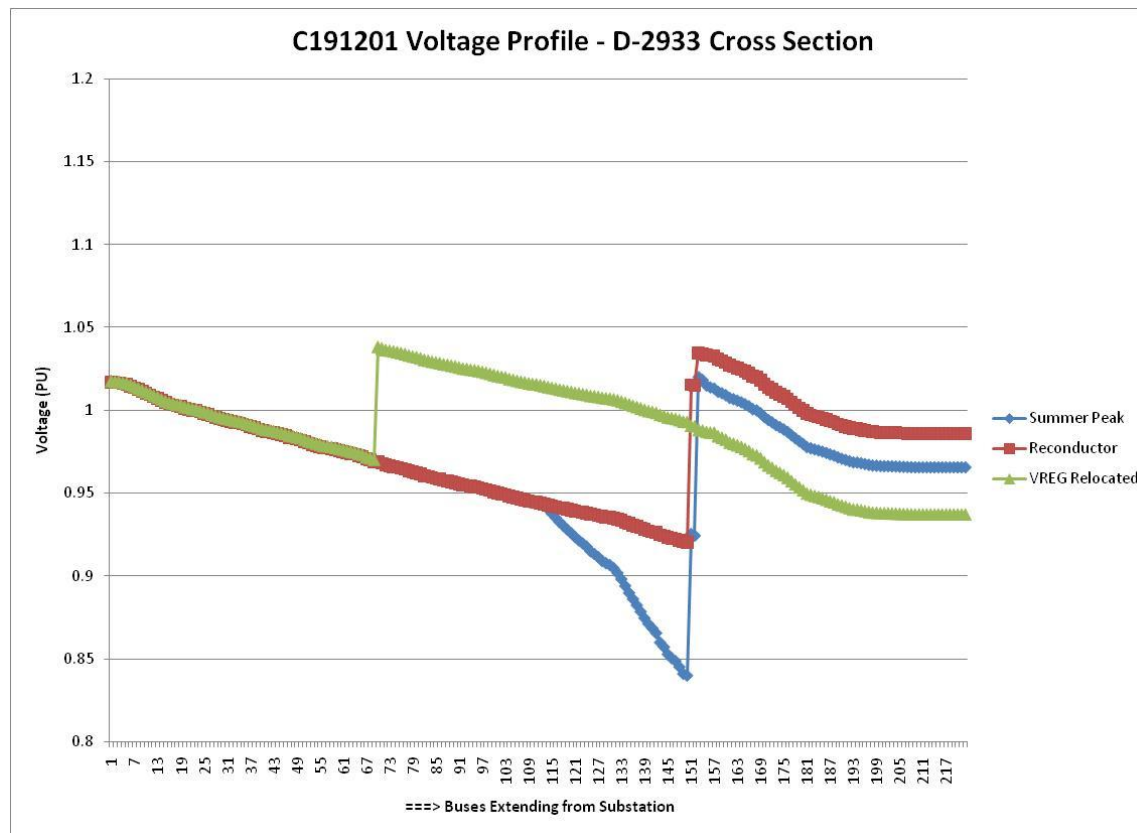
Turning data into situational awareness: => *Energynet* Simulation Validation



Turning data into situational awareness: *Energynet* Distribution Device-Level Visibility



Project Assessment - C191201 Reconductoring



➔ The impacts of individual projects are directly observable.

References

1. **Regional Transmission & Distribution Network Impacts Assessment for High-Penetration Wholesale PV, Evans, P. (New Power Technologies), CEC-500-2014-004; 2014.**
<<http://www.energy.ca.gov/2014publications/CEC-200-2014-004/CEC-200-2014-004.pdf>>
2. **Integrated Transmission and Distribution Model for Assessment of Distributed Wholesale Photovoltaic Generation, Evans, P. (New Power Technologies; California Energy Commission, CEC-500-2013-003; 2013.** <<http://www.energy.ca.gov/2013publications/CEC-200-2013-003/CEC-200-2013-003.pdf>>
3. **Verification of Energynet® Methodology, Evans, P.; California Energy Commission, CEC-500-2010-021; 2010.** <<http://www.energy.ca.gov/2010publications/CEC-500-2010-021/CEC-500-2010-021.PDF>>
4. **Optimal Portfolio Methodology for Assessing Distributed Energy Resources for the Energynet; Evans, P., California Energy Commission, CEC-500-2005-096; 2005.**
<http://www.energy.ca.gov/pier/project_reports/CEC-500-2005-096.html>

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The Energynet platform and its applications are protected under US Patent No.s 7,860,702 and 7,998,194 and patents pending.

About...

New Power Technologies is dedicated to moving advanced energy technologies from theory to practical application. The company's *Energynet*® technologies enable power delivery network analysis and management with unprecedented transparency, precision, and ease of integration to support high-performance and high-efficiency network operation and planning.

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